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Unmanned Combat Aerial Vehicles:
A Close Air Support Alternative

by

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Power is increasingly defined, not by mass or size, but by mobility and swiftness. Influence is measured in information, safety is gained in stealth, and force is projected on the long arc of precision-guided weapons. This revolution perfectly matches the strengths of our country—the skill of our people and the superiority of our technology. The best way to keep the peace is to redefine war on our terms.

President George W. Bush
Address to the Citadel, 1999

Abstract

Military operations since Desert Storm have taken an almost ultramodern style of warfare—a step away from the notion of sequential operations of the past, through the successful concept of parallel warfare during the Gulf War, toward a transformational strategy of network-centric warfare (NCW) now being adopted by the Department of Defense. The key technologies associated with NCW are information superiority, stealth, precision engagement, and a combination of manned and unmanned aerial platforms. Recent events around the world demonstrating the unique capabilities of the Predator Unmanned Aerial Vehicle have triggered a revolution in unmanned aerospace vehicle research. Proponents, including the President of the United States, are touting the Unmanned Combat Aerial Vehicle (UCAV) as the next generation bomber and fighter platform. This paper investigates the feasibility of an unmanned aerial vehicle as an alternative in close air support (CAS) operations. Can an unmanned airplane engage targets in close proximity to friendly troops with the same or better results than a manned aircraft? To better understand the military applications of UCAVs conducting CAS, several areas must be considered—doctrine, cost, survivability, distinct capabilities, and demonstrated accuracy. Unlike the aerospace missions of strategic attack, or the suppression of enemy air defenses (SEAD), CAS is unique, in that airborne operations are conducted in close proximity to friendly forces. This is problematic when addressing the issue of fratricide and fly and decide type decisions. While these issues are certainly unique to the CAS mission, human ingenuity is a much stronger force when faced with necessity. A stealthy UCAV armed with internal weapons offers increased capabilities in persistence, survivability, and responsiveness over a manned aircraft.

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CERTIFICATE

I certify that the creative process of researching, organizing, and writing this research report represents only my own work.

DISCLAIMER

CHAPTER 1

Introduction

“The future ain't what it used to be."
Yogi Berra

In one century airmen have evolved from open-air cockpits, through the sound barrier, to stealthy and unmanned platforms capable of engaging targets anywhere on the face of the earth. Despite this progress, the close air support (CAS) mission has evolved somewhat slower, almost as an afterthought to the missions of strategic bombing. CAS history since World War I can be characterized by debate, evolving doctrine, and a deficient national commitment. It is quite surprising that the US Armed Forces neglected to capture and codify the principles developed in close support operations throughout history. It became the norm to ignore the lessons learned in combat between the interwar periods, only to be ill-prepared in the next conflict.[1] Many factors contributed to the US ignoring these valuable lessons, but none more than the Army Air Corps' (AAC) quest for independence and the strategic focus of its airman.

Since Vietnam, CAS doctrine and procedures have improved and continue to be refined in modern-day warfare. CAS doctrine has been formalized, aircraft improved, and training continues between the services, yet the US military continues to struggle with the CAS mission, primarily regarding its responsiveness to ground maneuver units. As the current US Air Force (USAF) CAS-capable platforms, like the A-10, F-16, and AC-130, approach their useful service lives, what aircraft will eventually fill the upcoming CAS void? Logical reasoning would point to the Joint Strike Fighter (JSF); however, the unique characteristics of CAS may disqualify the JSF as a feasible successor. Perhaps there is another alternative?

The recent capability demonstrated by the armed Predator Unmanned Aerial Vehicle (UAV) represents a watershed event defining how CAS may be conducted in the future. Does an armed UAV have any utility in CAS operations? Can a UAV actually engage targets in close proximity to friendly troops with the same or better results than manned aircraft? President Bush is committed to the advancement of technologies involving armed UAVs, referred to as Unmanned Combat Aerial Vehicles (UCAVs).[2] UCAV technology combined with stealth offers endless military application possibilities across the entire spectrum of warfare and can only be understood with continued research.

Operating in Afghanistan, the RQ-1B Predator has demonstrated its capability to engage Al Qaeda and Taliban targets with punitive results. As UCAV technology demonstrators mature, it is essential for the military, especially the USAF, to explore and understand the future applications of these systems. Proponents of unmanned systems predict UCAVs will make up the preponderance of the force structure within the USAF by the year 2020, but are cautious to discount the importance of manned systems where target situational awareness is paramount.[3]

If UAV technology is to gain relevance as a potential CAS platform, UCAV systems must be cheaper than, and at least as effective as current or future manned systems. For the CAS mission this equates to the unique characteristics of survivability, distinctive capabilities, and accuracy. This paper evaluates the UCAV as a CAS alternative to currently manned aircraft and assesses whether this technology has the ability to increase the responsiveness of close support fire to ground maneuver units. The next chapter discusses the evolution of USAF CAS doctrine and aircraft. Chapter 3 outlines CAS joint doctrine, fundamentals and current CAS capabilities. Chapter 4 examines UCAV development and future roles and missions from an Air Force perspective. In Chapter 5, UCAV concept of operations (CONOPS) are dissected and evaluated, and finally, Chapter 6 answers the questions of whether UCAVs can perform the CAS mission and whether they possess the capability to increase the responsiveness of close support fire to ground maneuver units.

CHAPTER 2

US Air Force Doctrine and the Evolution of Close Air Support

"The reason I'm alive today is because of Close Air Support."
Joe Galloway, Vietnam War Reporter

Even though CAS operations can be traced back to the early 1900s, CAS doctrine was deficient during the first two decades of the 20th century. Following World War I, Billy Mitchell was one of the first to document the utilities of airpower. He codified airpower lessons in the 1918 "Provisional Manual of Operations of Air Service Units", describing tactics and procedures for observation, day-time bombardment, pursuit tactics, and attack operations.[4] Over the next few years, several Army officers published similar manuals; some supported Mitchell's strategic vision, while others opposed, claiming aviation merely augmented direct fire support. This chapter will review US Airpower and CAS doctrine before and after 1947 and recount the evolution of CAS and its application from Korea to Afghanistan.

Despite differing opinions within the US Army, both soldiers and airman similarly agreed upon the basic employment techniques of CAS. Aircraft design, communications, ordnance, and "bomblines" became common vernacular among CAS proponents.[5] Satisfied with the maturity of CAS doctrine, Mitchell and others set out to advocate the strategic potential of airpower. Mitchell campaigned to divorce the Army Air Corps (AAC) from the ground-centric Army, claiming airpower could be better utilized under the command of a single airman. The War Department argued that airpower would never be decisive in battle and that the AAC was best employed as direct support to ground maneuver forces. The fundamental core difference in this early airpower debate was at the doctrinal level; how and when airpower should be used and who had command and control of the forces.[6] While it may appear Mitchell and others ignored CAS doctrine in their zeal to promote bombers, they actually paid considerable attention to the mission, yet didn't publicize the utility of close support in fear they may dilute their forceful argument to advance strategic bombers.

During World War II, Germany and the Soviet Union made significant strides in developing close support doctrine, primarily employing their aircraft in support of ground forces.[7] In contrast, the US had committed to the idea of strategic bombing, paying little attention to developing an efficient air-to-ground control system. This became readily apparent in 1942 during the allied invasion of North Africa. Shortfalls in air-to-ground coordination techniques and command and control procedures hampered effective operations. Allied aircraft and ordnance were ill-equipped and failed to provide responsive support to advancing ground troops. CAS in the Pacific theater was not much better, experiencing similar shortfalls. Lack of radio-equipped aircraft and trained personnel limited effective ground support during the island-hopping campaign. Likewise, target identification was extremely difficult, procedures for bomb-fall deconfliction were lacking, and timeliness of support was abysmal, with some aircraft showing up the day following the air request.[8]

Despite early struggles, by the end of World War II effective procedures for CAS had been ironed out and published in Army Field Manual 31-35. However, these procedures were largely lost or ignored during peacetime training leading up to the conflict in Korea. The next test would be the Korean War and whether the newly independent USAF could deliver timely, accurate, and efficient CAS.

Korean War

American jet propulsion was introduced in combat during the Korean War. The high performance F-80 Shooting Star and F-84 Thunderjet, while exceptional in the interdiction role, were not as capable at identifying ground targets due to their high rate of speed. Moreover, while 500-pound bombs were available, the F-80 was not equipped with compatible suspension equipment, initially limiting the payload capacity to only rockets and guns.[9] Debate and finger pointing characterized the relationship between the ground services (Army and Marines) and the USAF. The US Army was skeptical of the Air Force's ability to integrate air and ground forces during CAS operations. The Marine Corps' aerial prowess and stellar track record in the close battle left the USAF struggling to compete. Although the AAC had made progress fighting alongside Navy and Marine pilots during the later half of WW II, all three services returned home to write their own CAS doctrine.[10] This was problematic, in that service parochialisms dominated the essence of each services doctrine…no two were the same. The Joint Training Directive (JTD) developed in 1950 served as the sole joint manual for air operations in the Korean War.

The USAF struggled with the other three services regarding the CAS debate. While the Army, Navy, and Marines believed airpower should be applied directly in support of ground troops, the Air Force claimed its primary focus was air superiority and interdiction.[11] Following the war, the JTD was declared defunct, sending the services back to the doctrinal drawing board. In 1953, the USAF published *Air Force Manual 1-2, USAF Basic Doctrine*, outlining its emphasis on strategic bombing and the centralized control of air operations. The Army focused on developing an autonomous air capability and independent CAS doctrine, signaling the demise of previously developed joint CAS doctrine.[12] In the years leading up to Vietnam, the USAF focused on the Cold War and transformation to a nuclear deterrent force. Again, the CAS mission became a low priority.

Vietnam War

More than any other period in history, the Vietnam War experienced a significant transformation in CAS capable aircraft. The neglect of CAS doctrine between the Korean and Vietnam War can be attributed to the service's focus on Cold War deterrence and compliance with the US national strategy of massive retaliation and flexible deterrence. With a nation focused on global nuclear war, little consideration was given to the CAS mission, or to developing sound joint doctrine. This reality fostered command and control disputes between the Army and the Air Force. Although an effective tactical air control system was eventually developed in 1965, the continued debate over close support assets caused significant delays in providing effective CAS.

In 1964, pilots found themselves replicating dated tactics and command and control procedures born ten years earlier. The O-1 Birddog used in Korea remained the primary USAF forward air control (FAC) platform.[13] Because of its lightweight and slow speed, it offered the best alternative. On the down side, it was vulnerable to small arms fire and lacked payload capacity. The F-80 was eventually replaced by the more maneuverable F-100 Super Saber fighter-bomber. What these aircraft gained in service ceiling and speed, they sacrificed in loiter time, an important characteristic for CAS shooter platforms.

Other than the platforms and weapons, basic CAS doctrine had not changed significantly since 1950. Once the FAC had identified a target, he requested fighter support to engage. With fighters overhead, the FAC described the target and issued attack clearance. The primary weapons utilized by the F-100 were 500-pound general-purpose bombs[14], napalm, and rockets. The rudimentary process of "talk-shoot-talk-assess" evolved throughout the war and was quite effective in South Vietnam, as witnessed by reporter Joe Galloway on 15 November 1965.

Reporting from Landing Zone (LZ) X-ray during the Battle of the Ia Drang Valley, 425 US Army soldiers were being overrun by the North Vietnamese. Realizing his fate, the commander, Lieutenant Colonel Moore, ordered the code word "Broken Arrow."[15] Within minutes, all available fighter bombers in South Vietnam were directed to X-ray to render CAS. For three hours, fighter after fighter bombed the approaching enemy allowing Colonel Moore to hold the LZ. While hugely successful, CAS operations were not perfect. Problems with establishing friendly demarcation lines resulted in occasional fratricide and fighters returned to base without expending ordnance because of their limited endurance.

In 1965, a positive doctrinal shift occurred when the Air Force and Army agreed to a system of apportionment and allocation.[16] Essentially, this concept allowed the Joint Force Commander (JFC) the opportunity to parcel available air assets to different mission priorities on a daily basis: air superiority, close air support, interdiction. This proved more efficient in prioritizing the airpower requirements of all services, especially CAS assets dedicated to the Army units on patrol. Many aircraft were called upon to support CAS missions. The aging World War II vintage aircraft, the B-57 Canberra and the A-26 Invader, flew CAS missions through 1968.[17] In the first four years of Vietnam, as many as eight different aircraft were modified or drafted for the CAS mission. What was needed was a dedicated aerial platform designed specifically for endurance, range, firepower, and robust communications.

As the air war dragged on, CAS became a mission priority. The US realized the necessity to develop a more capable and integrated CAS team. The answer was the O-2 Skymaster, the OV-10 Bronco, the Airborne Battlefield Command, Control and Communication (ABCCC) platform and more capable fighters (F-4 fighter-bomber and several US Navy jet aircraft). The Skymaster was capable of higher speed, better range and more endurance (loiter time) over the O-1. The OV-10, the first aircraft designed as a FAC platform[18], doubled the performance of the O-2, and added the capability to infiltrate four combat-loaded infantrymen. The ABCCC, a modified C-130, for the first time offered an airborne command and control function directly connecting ground forces with airborne aircraft. This vital airborne C2 node proved vital in reducing the response time for fighters dedicated to the CAS mission.[19] The Air Force and Navy fighters had better range and could carry more ordnance, but were forced to fly at medium altitudes to avoid anti-aircraft artillery (AAA), complicating target identification and weapons accuracy.

In a joint venture with the US Navy, the Air Force acquired the A-1E Skyraider, a propeller-driven low wing aircraft. Among its unique capabilities, the Skyraider possessed range, endurance, accuracy, and significant firepower. The aircraft and the pilots who flew them earned the reputation as the CAS kings for stellar performance in the close support role. Another innovative approach to performing CAS was the gunship. This concept evolved from the C-47 cargo plane to the more capable AC-130 platform, equipped with a 105mm howitzer and the most accurate targeting system to date. These aircraft proved highly effective in night perimeter defense of friendly base camps and were touted as the most accurate and responsive CAS platform in the inventory.[20]

Not all was lost during the Vietnam War. Although not a priority mission for the Air Force, a system was developed to allocate limited air assets to support ground troops. Additionally, the realization of the importance to match aircraft capabilities, ordnance, and doctrine became readily apparent. And finally, the foundation of current USAF CAS doctrine was developed during the conflict and would prove successful in the war against Iraq in 1991.

Desert Storm

Parallel warfare came of age during Desert Storm and would shape the Air Force vision for the 21st century. By leveraging advances in stealth technology and precision weapons capabilities, the US was no longer tied to the notion of sequential combat operations in order to roll back an enemy force before gaining access to strategic centers of gravity. Instead, parallel operations facilitated the application of lethal and non-lethal air and space power across the strategic, operational, and tactical levels of warfare simultaneously. The ace in the hole during Desert Storm was the stealthy F-117 Nighthawk fighter. No longer was stealth an untested concept; it had proven its utility many times over and had forever changed the nature of future warfare. Many of the concepts developed just prior to the Gulf War are still evolving and have been codified in the Air Force's most recent visionary document, Concept of Operations 2020. This document provides the basic framework for employing air and space power over the next two decades.[21] Even though the CONOPS does not mention specific aircraft platforms, stealth, precision, firepower, command and control, and global reach are common themes. In the midst of this transformation to a lighter, leaner, and stealthier force, one theme remains constant--future combat operations will necessitate the ability to conduct responsive CAS operations in support of ground units.

By the time Saddam Hussein invaded Kuwait in late 1990, the A-10 had been in the Air Force inventory for over twenty years and was on the verge of retirement. Known as the tank killer, the A-10 was the Air Force's answer to the ideal CAS platform. Designed in the early 1970s, it was developed to counter the Russian-built armor postured throughout Eastern Europe--again, a Cold War focus. The aircraft was slower than typical fighters, could loiter longer, and could carry almost any general-purpose munition in the inventory, including the precision-guided

AGM-65 maverick missile. Its GAU-8 gatling gun was capable of firing 1,150 30mm armor piercing rounds in one sortie giving it significant firepower. The aircraft flight controls were redundant and the pilot sat inside a titanium bathtub, making the A-10 the most survivable aircraft to date.[22]

Although CAS platforms flew throughout the air campaign, typical CAS operations were largely confined to the 100-hour war. Utilizing the Theater Air Control System (TACS) developed in Vietnam, the A-10 roamed the battlefield in front of friendly forces at the discretion of brigade and division air liaison officers (ALO) embedded with the Army forces. Flying at 500 to 1000 feet, utilizing classical Air Land Battle doctrine, A-10s identified and engaged enemy ground forces on the forward edge of the battle area (FEBA) before the enemy could engage friendly ground units. Working closely with the ground maneuver elements, the A-10 proved highly effective in engaging targets in close proximity to friendly forces, yet still managed to falter occasionally. Of the 247 friendly combat causalities, 35 were attributed to friendly fire incidents—fratricide, with 11 of those loses charged to air-to-ground missions.[23] This number is alarming, in that air-to-ground fratricide equated to 4.5 percent of all combat losses. The fratricide issue will continue as the Air Force continues to digitize the battlefield.

Aside from the fratricide, the realized success of the A-10 was accomplished without stealth, without Global Positioning System (GPS), and without precision- guided munitions (PGM) other than the maverick missile. While the Air Force had learned its lesson from ignoring history, it was quite evident that CAS had remained subordinate to other glamorous missions.

Operation Anaconda

Ten years later, American troops found themselves engaged in combat operations in Afghanistan. Fighting a war on global terrorism, US military planners soon realized that Anaconda would not parallel previous conflicts. The terrain was rugged and military access presented a unique challenge to US fighter and bomber platforms. Navy fighters launching from the decks of aircraft carriers flew more than 700 miles from the Indian Ocean and B-52 bombers endured a 2,500 mile one-way trip from Diego Garcia.[24] The enemy was ill-equipped and possessed an archaic air defense system, yet managed to conceal its location and movements, complicating US targeting opportunities.

The air war in Afghanistan was like no other. Within one week, strike aircraft had shifted from preplanned targets to targets of opportunity, or "flexible targets"; the majority of fighter pilots and bomber aircrews had no specific target information until after takeoff.[25] The ground target situation called for a different operational concept. The key was to keep a continuous flow of aircraft orbiting the battlespace until appropriate and valid targets were identified. After takeoff, fighters and bombers were relayed target information via voice or data link transmissions. Once inside Afghanistan, US fighters and bombers became a "roving strike force" positioned overhead to provide timely and precise targeting.[26] Airborne ISR platforms provided nearly 24-hour coverage of the battlespace, allowing for responsive reporting and engagement of time sensitive targets (TSTs), including senior officials of the Taliban and Al Qaeda.

The Predator UAV and satellites provided real-time intelligence and surveillance of forces on the move while B-52 bombers loitered overhead armed with the GPS-based Joint Direct Attack Munition (JDAM). While this was generally effective in destroying stationary targets, TSTs proved more difficult, with spotters on the ground sometimes waiting up to an hour before airborne platforms could put bombs on target.[27] At times, delays in targeting were due to the cumbersome target approval process. Unlike Desert Storm, where sensitive targets were pre-approved, orbiting ISR sources were required to relay target coordinates, and often times, images to the Air Operations Center (AOC) before final attack approval would be granted. On one occasion, a Predator operator was required to query the Central Command staff for approval to launch a hellfire missile.[28]

As armed unmanned systems become more prevalent in future warfare, the issue of weapons release consent needs to be solved at the doctrinal level to enable time critical targeting and responsive airpower. This will require a machine-to-machine interface of Command, Control, Intelligence, Surveillance, and Reconnaissance (C2ISR) systems through the horizontal integration of all battlefield systems to provide executable, decision quality knowledge in near-real time from anywhere in the world.

Global Strike Task Force

To ensure its ongoing transformation, the Air Force must create an environment and culture to allow for transformation. Air Force 2020 outlines this goal: "…to sustain the core competencies and the command and control through which they are employed in the face of the changing and emerging security environment through the use of innovation and adaptation."[29] The Task Force CONOPS construct is currently being developed as a transformational means to ensure global power, global reach, and global vigilance. At the heart of this construct is the Global Strike Task Force (GSTF), introduced by General John Jumper in 2001, as the commander of Air Combat Command. The GSTF is being envisaged as the Air Force version of the nation's "kick-down-the-door" force for the 21st century, utilizing stealth, precision, and machine-to-machine C2ISR technologies. The nexus of this rapid deployment force of shooters and sensors is a constellation of manned and unmanned platforms, satellites, and individuals with boots on the ground in close proximity to enemy forces.[30] The future dynamics of warfare require an integrated and automated intelligence collection architecture designed to sort through the overabundance of raw intelligence data capable of throughput distribution of the essential elements of information on a near-real time basis. That means building an eyes and ears seamless C2ISR architecture capable of transforming this data into legitimate and applicable threat information for commanders at every level.[31]

Undoubtedly, some of these threats may be in close proximity to friendly forces on the ground, requiring a capable airborne CAS platform tied into the C2ISR constellation. This may require a doctrinal shift in how the US military conducts CAS operations all together. As history has shown that as the nature of warfare evolves so must doctrine.

As the Air Force looks to the future, a balanced force structure is essential to preserve the unique capabilities across the spectrum of warfare. While budgetary constraints have driven the procurement of multi-role platforms, CAS will continue to play a strong role in supporting ground troops well into the future. Doctrine and training will continue to evolve as unmanned systems gain normalcy within US military joint operations. As the CAS mission is unique, so must be the performance characteristics of future CAS platforms. They must be survivable, accurate, and capable of supporting the ground troops in a timely and efficient manner.

CHAPTER 3

CAS Joint Doctrine, Fundamentals, and Capabilities

"Tiger 01 has killed more Taliban in 48 hours with CAS than the Northern Alliance has been able to kill in the previous year"
General Fahim Khan – Northern Alliance Commander

All four services doctrinally emphasize CAS as air action against hostile targets in close proximity to friendly forces, which requires detailed integration of each air mission with fire and movement of those forces. They also agree that CAS must be responsive, flexible, and timely and, due to the risk of fratricide, detailed planning and integration between aircraft, artillery, and ground forces is paramount. Aside from these similarities, each service tends to view the specifics of how to conduct CAS differently. At the heart of the debate are the USAF, the supplier of fixed-wing CAS, and the US Army, the beneficiary. Professor I. B. Holley, Jr.[32], a retired US Air Force Reserve Major General and key contributor to *Case Studies in the Development of Close Air Support*, clearly describes how parochial viewpoints are driven by service cultures.

> "Among military men it is commonplace that interallied and interservice operations inescapably pose grave difficulties in execution. Differences in equipment, in doctrine, in attitude and outlook stemming from contrasting past experience all inhibit and complicate harmonious interaction. Past successes, however, have shown that these difficulties can be overcome where determination is present and effective procedures have been applied by properly trained troops. Experience also shows that armed forces…have been slow to hammer out the necessary procedures. Often corrective steps have been achieved only after many failures in battle. In no area of the interservice operations has this phenomenon been more pronounced than in the matter of close air support."[33]

This chapter will explore the ongoing CAS debate between the Army and Air Force, briefly outline joint doctrine and the CAS environment, and summarize US CAS capabilities.

CAS Debate

At the heart of the CAS debate are the fundamental attitudes and culture of each service. Since the Army heavily depends on the other services to provide CAS, it is not surprising that the Army and Air Force are most at odds with the "how to" part of CAS. The two services disagree on several issues; among them are mission allocation, target nomination, night and weather capabilities, and the responsiveness of CAS.[34]

Mission Allocation

In principle, all services support the apportionment and allocation process outlined in joint publications--the rub occurs in practice. As discussed in Chapter 2, the apportionment responsibility lies with the JFC, who divides his theater air capabilities (Offensive Counter Air, Defensive Counter Air, SEAD, CAS, Combat Search and Rescue, etc) into percentages based on campaign objectives. The Joint Forces Air Component Commander (JFACC) translates those percentages into actual sorties based on the total number of aircraft in each category. For example, the CAS sorties are then distributed proportionately to Army Corps or Divisions through the Air Tasking Order (ATO). During Desert Storm, Army field commanders were not pleased with the JFACC arrangement, claiming that Horner's staff would leverage their position to showcase the decisiveness of airpower.[35] Their concern was understandable given General Norman Schwarzkopf's early JFC air priorities of air superiority and neutralizing Iraqi air defenses. Army commanders were more concerned about Iraqi artillery. This disconnect would continue throughout the air campaign and highlights the differing viewpoints of target nomination.

During the first two weeks of the air campaign, the Army nominated 1,185 targets, yet only 202 actually made it onto the ATO. Of those targets, no more than 137 were serviced by airpower; throughout the war only one-third of all Army nominated targets where struck by airpower.[36] The two examples above clearly illustrate how differing perspectives cause friction and wariness between the services. Army commanders are focused on the enemy directly in front of them and prefer fixed-wing aviation to target second and third echelon forces beyond their reach, while the Air Force prefers a balanced theater-wide approach, prioritizing targets that limit an enemy's ability to wage or sustain war. This is an important distinction and aptly describes the Army's skepticism where CAS is concerned.

Night and Weather Capabilities

An Air Force limitation to provide CAS at night and during degraded weather also concerns the Army. Although there are exceptions (AC-130), CAS operations at night or in the weather continue to pose a substantial risk to Air Force aircrews. Army doctrine embraces fighting 24 hours a day, preferably at night and during inclement weather. Although the Air Force has stepped up its night fighting training, current shortfalls in weapons and night vision technology limit its effectiveness to deconflict enemy and friendly forces in a fluid CAS environment.

Responsiveness of Airpower

Assuredly, the most often Army-cited criticism of the Air Force is the responsiveness of airpower. The Army has taken issue with the concept of immediate CAS, claiming the Air Force is not responsive enough to affect its scheme of maneuvers. Army commanders prefer assets under their direct control, similar to what they possess in organic artillery and rotary-wing aviation. The ATO is often the center of disagreement. The Army argues that the 72-hour ATO cycle is too rigid and unresponsive to its needs regarding immediate CAS operations, claiming it unrealistic to predict and integrate CAS operations three days in advance.

It is important to understand the core airpower issues between the two services, that being service-centric perceptions often become reality in the eyes of the beholder. Despite the services agreement on the basic concepts of CAS, there still exists some friction on how CAS is controlled and executed. Only through a thorough understanding of joint doctrine will the Army and Air Force allay the debate concerning timely and responsive CAS operations.

Joint Doctrine and CAS Fundamentals

Joint doctrine provides for standardized and situation-specific procedures relating to the conduct of warfare. Joint Pub (JP) 3-09.3, *Joint Tactics, Techniques, and Procedures for Close Air Support (CAS)*, outlines the fundamentals of CAS and highlights several areas of particular importance relevant to the idea of employing UCAVs in the close support environment; most notable are the conditions for effective CAS, the unique characteristics of CAS operations, and finally, the fundamentals of the mission.

Conditions for Effective CAS

Due to the distinctive planning and coordination required for and during CAS operations, the environment and certain conditions are central to success. JP 3-09.3 delineates nine conditions essential for effective CAS: air superiority, SEAD, favorable weather, prompt response, target marking/identification, terminal controller (TC) skill, appropriate ordnance, communications, and command and control.[37] Together, these conditions do not represent a panacea for CAS operations, but if followed in principle, can lead to effective, timely, and responsive CAS regardless of aircraft type. Some of these conditions will be discussed further in the fundamentals of CAS below.

Characteristics of CAS

JP 3-09.3 defines CAS as "air operations providing firepower in offensive and defensive operations to destroy, disrupt, suppress, fix, or delay enemy forces in close proximity to friendly forces…CAS requires detailed planning, coordination, and training for effective and safe execution."[38] What makes CAS so characteristically different from other missions is that it is conducted in close proximity to friendly troops. The word "close" is not defined by a specific distance; instead it is intended as a situational term.[39] The necessity of detailed integration of maneuver and fires to prevent fratricide is the driving factor which delineates CAS from other missions. For this one reason, extensive coordination and planning is required between participating friendly forces. It is imperative that functional C2 systems are maintained and executed and that weapon systems of the future, manned or unmanned, have the ability to differential between enemy forces, friendly forces, or a combination of both. In no other air-to-ground mission is the decision to release or retain weapons more critical than in the business of CAS. Along with the many fundamentals of the CAS mission, the fratricide issue will weigh heavily on the decision whether UCAVs can be effective performing the close CAS mission.

Types of CAS

There are two types of CAS: preplanned and immediate. The above process generally describes preplanned CAS where mission requests compete for inclusion on the ATO based on priorities and CAS apportionment percentages. Immediate CAS requests are usually generated from below brigade level in response to unexpected enemy actions.[40] If approved, preplanned CAS missions may be diverted to cover the immediate request, or CAS alert aircraft may be scrambled depending on the situation. Another option to increase responsiveness of immediate CAS requests is via Push CAS. This concept is nothing more than a practical proactive concept of pushing CAS assets into the battlespace juxtaposed to the standard request-driven method mentioned above.[41] Push CAS missions are planned and flown anticipating the supported ground commander's request. In essence, Push CAS provides the supported ground commander a constant flow of airpower to be used at his discretion. While this approach risks efficiency, it maximizes response time when ground forces are providing the main effort. This tactic was successfully employed in Desert Storm and dates back to World War II.[42]

CAS Fundamentals

It is important to understand the fundamentals of the CAS mission before alternative platforms are explored. At the doctrinal level the TACS is the operating architecture designed to facilitate CAS operations and is heavily dependent on the functionality and integration of subordinate C2 nodes. Briefly, the categories of C2 nodes are: the TC, the ground C2 system, the aviation C2 structure, and the weapon system or delivery vehicle.[43]

The TC, usually an airborne or ground FAC operating as a tactical air control party (TAC-P), functions as the liaison between ground elements and the delivery platform and is responsible for the safe conduct of weapons delivery. The ground C2 node is responsible to review the allocation of fixed-wing resources and to coordinate ground element CAS requirements with the aviation C2 node. The aviation node receives the daily JFC CAS apportionment decision and is responsible to allocate sorties to ground maneuver commanders. Once the allocation process is complete, CAS sorties are printed and distributed to the delivery platforms (aircrews) via the daily ATO.

At the heart of the TACS is communications. Without information or communication connectivity, CAS is impossible. Immediate CAS missions are extremely dependent on communications due to the immediacy of the situation. Often, pilots launch knowing little more than a frequency, callsign, and the general area of the tasking. Generally, mission essential information, threat data, target location and type, and friendly locations are relayed while the aircraft is airborne. In the execution of a single CAS mission, detailed coordination is required between the pilot flying the aircraft and the TC. In-flight briefing items are covered to include heading and distance to target, target description, type ordnance requesting (if carrying multiple types; cluster bombs, PGMs, or gun), attack restrictions, and weapons release clearance authority. Detailed coordination often requires ten minutes before final attack preparations begin, making loiter time critical. If multiple passes on different targets are requested, an aircraft could easily loiter in a hostile environment for up to 30 minutes, assuming targets can be identified.

Target acquisition is fundamental to effective and responsive CAS. It is most commonly accomplished visually; however, aircraft sensors and avionics (LITENING II PODS, Situation Awareness Data Link (SADL), GPS-INS) aid the pilot in identifying the target quickly. Not only is target acquisition essential, knowing the position of friendly forces in relation to the target is imperative. A mix of specific aircraft capabilities to build situational awareness, combined with sound tactics, will maximize target acquisition opportunities and survivability.

CAS Capabilities

In reviewing the definition of CAS, it becomes clearly obvious that no service attaches one specific aircraft system to close air support. Rather, all four services define the nature of CAS…air actions conducted against hostile forces within close proximity to friendly troops. This definition is useful in the evaluation of CAS capabilities, in that any airframe that is capable of accurately delivering munitions close to friendly troops should be classified as CAS capable. Perhaps, but in consideration of the conditions and fundamentals of effective CAS, platforms classified as CAS-capable should be survivable, uniquely capable, and accurate, especially in studying the UCAV's utility in this role.

Survivability

Even though advances in weapons technology permit greater standoff ranges with similar or improved accuracy, a platform's ability to survive in a hostile environment will depend on its ability to get into a weapons range, deliver the munition, perhaps loiter, and then egress. Certainly stealth, speed, and a dependable flight control system will enhance survivability; however, each conflict presents distinct and emerging challenges. In Operation Allied Force, the coalition failed to destroy the Croatian air defense system, forcing coalition aircraft to fly only when embedded SEAD assets were available.[44] In contrast, during Operation Desert Storm, the Iraqi Kari Air Defense System was so splintered that coalition aircraft roamed the skies above 15,000 feet virtually unthreatened. Stealth has become a baseline requirement for future shooter platforms. While it is expensive, the survivability tradeoff outweighs any monetary burden. By utilizing stealth technology, enemy access-denial threats are minimized, increasing the survivability of US platforms.

Speed is relative and is another characteristic that makes aircraft survivable. As seen in Vietnam, the speedy F-100 and F-4 were outclassed in the CAS environment by the much slower A-1E. It was survivable, but not too fast to identify ground targets in rugged terrain. The A-10 is another example of where speed is relative. It is much easier to positively distinguish friendly and enemy troop lines while flying 325 knots versus over 450 knots in the F-16.

Uniquely Capable

A uniquely capable CAS platform possesses endurance (loiter time), range (air-refuelable), substantial firepower, and is integrated into the communications network of the

TACS (sensor-to-shooter, data link, GPS, and situational awareness tools). On a typical CAS mission, aircrews are required to accomplish a variety of tasks prior to releasing the first weapon, requiring considerable loiter time. Although advances in sensor-to-shooter technologies will shorten this coordination cycle considerably, endurance provides longer on-station times which equates to responsiveness. CAS platforms must be air-refuelable, or possess through aerodynamic technologies the ability to remain airborne for extended periods of time, similar to a B-2 bomber or Global Hawk UAV platform. This will become even more important in future conflicts. Likewise, firepower is the bread and butter of CAS platforms. This includes appropriate weapons and enough carriage capacity to affect multiple targets during a single mission. An example of firepower is a B-52 armed with 48 JDAM munitions or an A-10 armed with the 30mm GAU-8 cannon, or a UCAV configured with 12 small diameter bombs (SDB) carried internally. In order to deliver these weapons, a CAS platform must possess the capacity for accuracy under fire.

Accuracy

Accuracy can be attained by many means: GPS, lasers, directed energy, and even through combat proven weapons delivery techniques of general purpose munitions. Whatever the method, accuracy will be crucial for future CAS platforms. Additionally, accuracy in identifying target information through data link or situational awareness tools similar to the already fielded SADL on F-16 and A-10 aircraft, will be expected.

This chapter has highlighted several issues that will influence the development of future CAS-capable systems. Service parochialisms will ultimately affect how future doctrine is developed and how CAS is conducted on the battlefields of the 21st century. As technology speeds forward, aircraft systems will become more complex, incorporating stealth and sensor-to-shooter data link capabilities increasing survivability, accuracy, and efficiency. Yet, future force planners cannot ignore the fundamental capabilities required of next-generation CAS platforms—range, endurance, firepower, and communications connectivity. The next chapter will outline the current Air Force UAV systems, describe the X-45 UCAV program and capabilities, and investigate the utility of the UCAV as a CAS platform.

CHAPTER 4

Unmanned Combat Aerial Vehicles

"The complementary nature of unattended vehicles with manned systems is something we have become more and more comfortable with."
Dr. James G. Roche, Secretary of the Air Force

Over the past decade UAV technology has gained significant relevance as an ISR platform and is now being touted as the first generation of air combat vehicles. The Bush Administration and Congress are backing the defense industry to develop a fleet of unmanned combat aircraft in an attempt to reduce defense spending and loss of life during the most risky combat missions.[45]

Together the USAF and the Defense Advanced Research Projects Agency (DARPA) are developing an Advanced Concept Technology Demonstrator (ACTD) to demonstrate the technical feasibility and military utility of a UCAV system to effectively and affordably prosecute SEAD, Electronic Attack (EA), and Deep Strike missions.[46] The ACTD program includes the X-45A/B air vehicles, a mission control station, and a shipping and storage container.[47] Boeing is currently flight testing the X-45A air vehicle and expects B-version vehicles to carry weapons and demonstrate air-to-surface attack operations in the near future.[48] In theory, these aircraft will navigate and fly themselves to a target, release bombs, and return to base with little to no input from a ground station controller.[49] If UCAVs prove successful as an emerging technology, will they eventually be capable of providing direct combat support to troops on the ground?

As outlined in previous chapters, the CAS mission is unique in that air operations are conducted in close proximity to friendly troops. At this stage in the game, the dynamic FEBA situation is too tough of a scenario to tackle initially due to the necessity for complex coordination between ground and airborne forces involved.[50] Instead, the Air Force is focused on exploiting missions that require less coordination and integration before investigating follow-on applications. Nonetheless, much can be learned and applied to a CAS scenario from current UAV systems and emerging UCAV demonstrators.

UAV Systems

Unmanned Aerial Vehicle systems are rapidly coming to the forefront of military operations and are providing combatant commanders an unprecedented perspective of the battlefield. Both the unmanned Predator and Global Hawk UAV systems were pulled out of research and development and rushed into the field to fill a huge ISR void. The DoD has already launched a joint UAV Planning Task Force with oversight to examine the future missions of UAV technology, focusing on immediate military applications.[51] As evidenced by the nearly $1.2 billion annual research budget, the US is unmistakably committed to developing a fleet of UAVs and UCAVs. Colonel John Warden, a retired fighter pilot and renowned airpower strategist, predicts that UCAVs will make up ninety percent of the US military force structure by 2020.[52] While an unmanned force structure of this size won't be cheap, the idea of losing a UCAV in combat is more agreeable than risking human lives. Already the Predator has proven its persistent precision strike capability versus Taliban forces in Afghanistan and Al Qaeda terrorists in Yemen.

RQ-1B Predator

The $40 million RQ-1B is the armed version of the medium altitude, long endurance UAV system[53] designed for theater level reconnaissance, surveillance, and target acquisition. It is powered by a four cylinder 100 horsepower engine and is capable of cruise speeds up to 120 knots, a service ceiling of 25,000 feet, a range of 400 nautical miles, and a payload of 450 pounds. The vehicle has been equipped with the Multi-Spectral Targeting System and two AGM-114 Hellfire missiles. The sensor package is capable of electro-optical, infrared, laser designator, and a laser illuminator.[54]

The Predator system is controlled by a rated USAF pilot and two sensor operators and is capable of 24-hour operations.[55] The vehicle is controlled from a ground control station utilizing a Super High Frequency (SHF), C-Band line-of-sight data link or for long-range over-the-horizon operations, via a SHF, Ku-Band satellite data link. The Predator vehicle is equipped with a color nose camera (used primarily by the operator for flight control), a day and night variable aperture TV/IR camera for low light/night acuity, and synthetic aperture radar (SAR) for viewing options through smoke, haze, and clouds.[56] The cameras provide full motion video and the SAR detailed still photos.

RQ-4 Global Hawk

The RQ-4 Global Hawk system is a high-altitude, long-range, long-endurance UAV. Unlike the Predator, this system was designed for autonomous operations[57] with man-in-the-loop (MITL) technology allowing real-time route and profile changes, depending on air traffic control or mission requirements. The aircraft design calls for a 340-knot cruise at 65,000 feet allowing for loiter operations up to 40 hours 1,380 miles from base.[58] Although still in flight test, the Global Hawk is currently supporting Enduring Freedom operations in Afghanistan.

Similar to the Predator, the Global Hawk is equipped with EO/IR and SAR sensors, but adds a signals intelligence and ground moving target (GMT) capability. On April 22-23, 2001, the Global Hawk flew for 30 hours and 7,500 miles nonstop from California to Australia, setting a new world record for UAV endurance.[59] The success of these UAV systems in testing and combat operations has convinced the military, primarily the Air Force, that the UCAV concept displays substantial promise as an attack platform and is inexpensive enough to compete with manned systems of the future. The X-45 project is the next step.

X-45 UCAV Concept Demonstrator

Figure 4-1

The Boeing-designed Y-shaped X-45 UCAV system is an experimental aircraft with a promising future. Already in the flight-test phase of development, flying characteristics and flight control software have proven successful. Originally, the program was envisioned as an affordable reusable unmanned UCAV costing half that of an F-16 and 75 percent cheaper to operate and maintain.[60] Substantial operations cost savings would be realized through the use of climate-controlled storage containers, allowing for system health monitoring and software upgrades for up to ten years.[61] The operations and maintenance savings alone would dramatically lower the life-cycle cost of an unmanned system, experiencing a much lower training loss rate as compared to manned systems. As of 2000, 261 of the 265 F-16 aircraft lost to Class A mishaps occurred during peacetime training.[62] The X-45, with its wings detached, could remain crated until needed, shipped via airlift, then unpacked and serviced for flight operations. According to USAF Chief of Staff General John Jumper, as the Air Force studied the concept of pack-mobilize-unpack-fly, the notion of rapid was somehow lost in the proposed solution. So instead, an air refueling capability, a larger weapons bay, and additional fuel capacity were added as key requirements to allow for power projection.[63]

Now the X-45 UCAV is being viewed as an unmanned bomber, larger in size with an extended range, and a weapons bay identical to the JSF, allowing for 3000 pounds of internally carried ordnance. General Jumper is optimistic that the evolving requirements of the UCAV concept can be efficiently balanced against rising costs. In the end, the USAF cannot afford to develop another fleet of ultra-expensive platforms (B-2) that can only be used in unique combat environments. Using the X-45B aircraft as a baseline capability, the following section will explore the utility of the UCAV as a potential CAS platform in the following critical areas: cost, survivability, range and endurance, firepower (payload), and sensors and communications.

Cost

In the current age of restrained budget authority, military procurement programs are being highly scrutinized by the DoD and Congress. Due to the rising cost of technology and the transformational nature of unmanned systems, UCAVs of the future will face the same or a greater level of scrutiny than the F/A-22 and JSF programs. In order to gain support, UCAVs must be cheaper to operate and easier to maintain than manned systems.

Most proponents of UCAVs agree that unmanned platforms will ultimately cost less per unit than manned aircraft, but will require significant research and development before the first systems are operationalized.[64] Undoubtedly, millions, if not billions, of dollars will be spent developing this infant technology. The Global Hawk is estimated to cost $50 million per copy, about equal to the U-2, the system it replaces. Last year, DARPA estimated that the UCAV would cost less than one-third of the JSF, or approximately $12 million per unit,[65] though, this figure has since risen as the program requirements have changed. While these additions weave UCAV capabilities into the expeditionary mindset of the Air Force concept of operations, they also increase unit costs.

Stealth is another primary cost driver. Without a pilot in the cockpit, UCAVs are smaller and much stealthier than manned systems.[66] Stealth provides increased survivability but may not be required in the CAS environment; however, today's procurement realities limit the military's options to field single-role aircraft like the F-15. Tomorrow's air systems must be capable of performing multiple missions--SEAD, Strategic Attack, and/or CAS. As such, UCAVs must possess stealth characteristics allowing survivability in many different missions.

Survivability

Due to the cost factor and unique C2 capabilities of future stealthy UCAV systems, survivability in combat roles will weigh heavily on how theater commanders choose to integrate unmanned systems. In the CAS environment, the dynamic nature of force-on-force combat operations poses unique risks to aircraft flying over the battlefield. If UCAVs are to provide classical CAS to ground troops, survivability must be a forethought for UCAV designers; stealth, speed, and a smart flight control system are a few characteristics to consider.

As an aforementioned characteristic, stealth is the future of air combat operations. It has almost become common vernacular in describing future fighter and bomber platforms. One only needs to look at the future USAF force structure: B-2, F/A-22, JSF, and UCAVs. Stealth is an enabler, and although not crucial for CAS operations, it will allow dual-role platforms the ability to swiftly penetrate enemy defenses unscathed. As the old saying goes, "speed is life" in combat operations. This is not completely true but, is a very important consideration for UCAVs conducting CAS operations. The air vehicle must be fast enough to maneuver and sustain energy efficiently, yet not fly so fast that target identification becomes a problem, as was the case in Vietnam. Too slow also presents unique challenges in windy conditions. In a no-wind situation, the Predator travels only 100 nautical miles in 60 minutes, a tremendous liability when dealing with TSTs or battlefield coverage. A high subsonic speed of 350 to 400 knots should prove effective; however, slower speeds may be prudent when combined with typical threat avoidance tactics of over flight and standoff. Sensor technology will also allow for standoff identification of enemy targets, thus minimizing the time UCAVs spend within the threat rings engaging targets, but will never totally eliminate the "Golden BB" possibility.[67] A smart flight control system will enhance survivability.

A smart flight control system will allow the UCAV to execute basic flight functions should data-link connectivity be interrupted, or in the case of battle damage. Should MITL data-link interruption occur (signals jamming or deception), an automated flight software program capable of autonomous flight operations could prove the difference between recovering the UCAV safely or dropping it in the dirt. Battle damage is highly likely in a classical CAS scenario. Redundant computerized flight control and hydraulic systems would increase the survivability of an expensive UCAV platform. In future years, flight controllability could include a broader range of more survivable flight characteristics to include supersonic and hypersonic flight and maneuverability limits in excess of normal human tolerances.[68]

Range and Endurance

As was discussed earlier, range and endurance are key characteristics of effective CAS platforms and, if ignored, can leave ground troops without critical support. First and foremost, any new system, manned or unmanned, must be capable of force projection and employment. The current design of the X-45 allows for an air refueling receptacle and additional internal fuel capacity allowing it to deploy overseas just the same as conventional manned aircraft have done for years. From an employment perspective, the unrefueled range of the X-45 is parallel to the JSF—a 650 nautical mile combat radius.[69] Theoretically, depending on the threat level, an air-refuelable UCAV could reconnoiter a battle zone for hours, or even days, awaiting tasking, limited only by weapons payload. From a standpoint of endurance, no manned fighter aircraft in the current inventory possess the potential stamina of the UCAV.

Firepower

For CAS operations, firepower is the name of the game. If the UCAV is to be employed in future CAS roles, a Predator payload of two Hellfire missiles may not carry enough punch to warrant its use against large enclaves of enemy forces. A larger number of small accurate munitions would allow the UCAV to carry enough weapons to optimize its endurance and pack a lethal punch while minimizing collateral damage. The X-45 UCAV's planned payload is twelve 250-pound SDBs, the equivalent payload of the JSF.[70] The small-diameter bomb (SDB) is being designed for the precision attack of fixed targets as well as the tougher mobile targets that proved so difficult in Kosovo. Utilizing a four-phase approach, the USAF plans on fielding the initial SDB capability in 2006, with follow-on, more capable versions in 2008 and beyond.[71]

The SDB becomes a key enabler of weapon systems of the future, including the X-45 UCAV. By design, its miniaturized size permits smaller and stealthier platforms the capacity to carry similar combat payloads of the A-10 and F-16 aircraft. It also offers significant improvements in precision—from 35 miles, it has an accuracy of 13 meters.[72] Armed with the SDB and future miniaturized munitions, the UCAV will pack a lethal punch capable of destroying multiple targets on a single mission while loitering overhead a area of interest for extended periods.

Sensors and Communications

From a CAS standpoint, sensors and communications represent the heart and soul of the UCAV system and will ultimately determine whether UCAVs are compatible with the close air support role. As previously defined, CAS requires detailed planning and integration between aircraft, artillery, and the ground forces. This coordination has historically fallen on the shoulders of the pilot and the TC. By taking the pilot out of the cockpit, sensor and communication capabilities will supplant the human decision making element of targeting and target data transfer.

Advanced technology in electro-optical, infrared, SAR, and radio frequency passive and active sensors will be required to accurately find, fix, track, and engage stationary and mobile targets in a dynamic and fluid environment. What's more, target recognition technology becomes necessary to ensure demarcation between friendly and enemy troops. In other words, a wide field-of-view, continuous eyes-on-target sensor for an agile low flying UCAV must be developed to provide simultaneous battlefield situational awareness and pinpoint targeting.[73] Already, UAVs have proven effective in providing real-time surveillance and targeting data across the globe; however, weapons release authority remains tied to human reasoning and logic. Future UCAV sensor and communication technology must allow for MITL interpretation of mobile targets and provide an almost fail-safe kill chain to prevent fratricide. This will prove difficult, especially when trying to convince the US Army that a UCAV will engage targets within 1 kilometer of their position.

On-board signals intelligence processing, decision aids, and data link capacity must afford a satisfactory level of autonomy and MITL decision making.[74] Much of this technology already exists and has been tested in the field. In 2001, Block 30 F-16Cs equipped with SADL demonstrated the ability to conduct communication-out daytime CAS operations supporting SADL-equipped ground units at the National Training Center. Utilizing data link integration, F-16 pilots received digitized nine-line briefs from ground TCs, including weapon release authorization, abort codes, and visual displays of friendly positions (through their Heads Up Displays) without speaking. Although a baseline communication capability, SADL represents the most fundamental technology and integration required on tomorrow's battlefield—the ability to pass digitized information through a secure network to quickly and efficiently get bombs on target when and where they are needed without a man in the cockpit.

While certainly not all encompassing, the critical areas of cost, survivability, range and endurance, firepower, and sensors and communications, are as applicable today as they were in Korea and Vietnam and are key in defining the characteristics of a CAS-capable UCAV. DARPA's X-45 offers significant transformational technologies suited for many air missions, including CAS. However, a better understanding of how the UCAV will operate within the battlefield constellation of manned and unmanned systems is required. Using the *Air Combat Command (ACC) Concept for Operations for RQ-1B Multi-Role Endurance Remotely Operated Aircraft* as a baseline framework, the next chapter will outline a theoretical concept of operations for future UCAV systems as they relate to the CAS mission.

CHAPTER 5

UCAV Concepts of Operations

"We've come a long way from 10 years ago [Operations Desert Storm], when we had to fly the ATO out to the aircraft carriers."
General John P. Jumper, USAF Chief of Staff

A new fleet of unmanned aerial combat vehicles is abruptly taking shape on the drawing boards within the Pentagon. Leading the charge is long-time fighter pilot and Chief of Staff of the Air Force, General John Jumper. General Jumper envisions the operational need for an unmanned system or architecture to augment and even replace over tasked manned systems, especially for dangerous and mundane missions. Pursuant to his vision, General Jumper is working closely with his staff and the defense industry to develop and formalize a UCAV concept of operations. As the Air Force moves closer to fielding a sizeable UCAV force, it is consequential to understand the operating architecture and roles and missions.

UCAV CONOPS

Even though the X-45B UCAV possesses unique multi-role characteristics, an unmanned system requires a secure robust command and control network designed to leverage the complete spectrum of unmanned capabilities. The following statement drawn from the DoD UAV Roadmap accurately expresses two entirely different approaches.

> "The most fundamentally, technology-driven decision facing UAV planners early in 2000-2025 timeframe is whether to migrate towards an air-centric…processor based, or ground-centric…communications based architecture. In the case of the former, relatively autonomous UAVs with minimal ground infrastructure and direct downlinks to users will be the norm. For the latter, UAVs will be [remotely piloted] sensors feeding a variety of data into centralized ground node which builds a detailed, integrated picture for users."[75]

Even though regarded as the standard for future UCAV systems, a totally autonomous UCAV system where vehicles "fly and decide" with nominal input from ground stations is still rather troublesome, especially regarding engagement decisions. Until technology can provide an autonomous target identification capability, a ground-based MITL decision practice is the only acceptable protocol.

To better understand the operational concept of future UCAV command and control architectures, one should consider ACC's newly developed ground-centric communications based architecture for the Predator UAV system as a baseline framework. The CONOPS calls for a system within a system capable of merging the functions of Find, Fix, Track, Target, Engage, and Access (F2T2EA) into a single asset reducing the sensor-to-shooter timeline versus TSTs.[76] The JFACC would maintain Operational Control and deconflict all unmanned systems through the normal ATO process. Command and control through the AOC would allow the multi-role vehicles to almost instantaneously transition between the lethal and non-lethal roles offering flexibility and responsiveness.

Robust communications and sensor suites offer a wide range of unique capabilities. Precision coordinates and small smart bombs provide a precision strike capability against high value and mobile targets. Real-time fused hyper-spectral video links and machine-to-machine interface provide for unique counter-deception capabilities with instantaneous battle damage assessment (BDA).[77] SAR and GMTI provide a through-the-weather precision engagement and wide field of view search capabilities. Each vehicle will be equipped with standard electronic bus architectures and external weapons hard points capable of specialized weapons carriage.

The low and high-altitude Predator UAVs will work in conjunction with other coalition manned systems forming hunter-killer teams capable of performing the full spectrum of Air Force missions.[78] A low and high–altitude target detection capability allows for PGM-quality coordinates to be passed through the architecture to other networked platforms. When supporting manned strike assets, they are capable of performing Killer Scout and FAC-A missions directing weapons employment using standard joint doctrine.[79] This framework offers a glimpse of future UCAV architectures and the realization that CAS conducted by unmanned systems is not that far off.

The operational concept for future UCAV systems allows for a single operator to control at least four UCAVs simultaneously. Because UCAVs of the future will be highly intelligent and capable of flying preplanned routes without direct input, the operator will only monitor mission progress and intervene when necessary. For instance, a UCAV(s) could be pre-programmed to takeoff, fly to a preplanned orbit location, loiter for 12 hours, then return to base and land without operator input. However, if while loitering, an Army unit requested immediate CAS support through the TACS, the operator could command a route change and direct the UCAV(s) to an alternate location near the FEBA, where vehicle control would be transferred to a UCAV sector controller (USC).[80] The USC would function as the nexus between the ground control station operator and the forward friendly ground forces, just the same as FACs and TAC-Ps function today. Handoff operations from one controller to the next must be automated, seamless, and redundant from several different links to ensure continuous positive control.

Once positive control is transferred to the USC, the amount of direct controller input would be mission-driven. For a static strategic target, the pre-programmed attack profile would permit the UCAV to detect, deconflict, and cooperate with other unmanned and manned aircraft in the strike package, prioritize weapon selection, and capture BDA video before returning to base.[81] Release consent would remain with the USC, but in this case could be granted early in the kill chain. For CAS, the process of controlling a lethal unmanned system in close proximity to friendly troops becomes more complex because of the issue of *final attack control* and *clearance to drop authority* outlined in joint doctrine. These procedures have been written in friendly blood and cannot be ignored.

Final Attack Phase

During final attack control, the TC (TACP or FAC) is responsible to provide target and threat updates to aircraft attacking the target. Most often transmitted via secure radio transmissions, the TC relays last minute target descriptions, friendly disposition, and attempts to visually acquire the CAS aircraft to offer final corrections prior to ordnance release. The final attack control phase may take up to ten minutes depending on the complexity of the battlefield situation.

The TC has the authority to clear pilots/aircrews to release ordnance only after the ground commander has given general and/or specific release approval. Two levels of release authority exist: *positive control* and *reasonable assurance*; both deserve discussion. JP 3-09.3 directs the use of *positive control* to the maximum extent possible. The TC or an observer must be in a position to observe the attacking aircraft in order to establish positive target identification and to prevent fratricide. Pilots/aircrews are prohibited from releasing ordnance until a "cleared hot" call is passed by the TC. Positive control can be accomplished via direct or indirect control with direct control being the preferred method. Direct control implies the TC is visual with the attacking aircraft and is in a position to control the attack. In the case that a TC cannot see the attacking aircraft (weather, sun angle, standoff weapons, night), drop clearance can only be granted if he is positive the aircraft has identified the correct target. Another form of positive control is indirect control, which, as its meaning connotes, is actually not very positive. It allows the TC to issue drop clearance based on the inputs from a forward observer.

The second level of release authority is r*easonable assurance,* which can only be implemented by the JFC. This procedure accounts for the fog and friction of combat operations that prevent positive clearance authority, and if authorized, is formally outlined in the ATO. When implemented, *reasonable assurance* permits attacks to continue if the maneuver force commander, TC, and aircrew are confident the attack will not harm friendly forces. Because of the requirement for complex coordination during the final attack phase, UCAV employment within close proximity to friendly troops becomes problematic, but not insurmountable. Through technology integration with systems and sensors similar to SAR, GMTI, SADL, Link 16, and a secure machine-to-machine battlefield network constellation, final attack clearance may be easier to transmit to a UCAV than to a manned aircraft.

Battlefield CAS Zones

With minor adjustments to CAS *final attack control* doctrine, UCAV technology could prove very efficient in the CAS environment. It may be prudent to conceptualize a tiered three-dimensional battlespace sectored into three separate zones between the Forward Line of Troops (FLOT) extending forward to the Fire Support Coordination Line (FSCL): a close zone, a medium zone, and a deep zone.[82] Generally, air operations conducted short of the FSCL require coordination with the owning ground commander and are categorized as CAS. However, CAS doctrine does not differentiate zones or recognize the triple-tiered approach. The Close CAS zone stretches from the FLOT extending forward into the enemy zone to a distance of 7,500 meters (4 NM), defined by the ground element's organic direct fire ranges. In this zone, CAS operations require extensive coordination and terminal control to prevent fratricide. The Medium CAS zone extends from the end of the Close Zone out to approximately 18 kilometers (~ 10NM) and is nominally defined by the range of self-propelled artillery systems. The majority of targets in this zone are enemy, except for small friendly scout teams that can be easily deconflicted from artillery fires and CAS sorties. The third zone is the Deep CAS zone, which begins just beyond the Medium CAS Zone and extends forward to the FSCL, generically defined by the capabilities of long-range artillery fires, or 30 kilometers (16 NM). Typically, only airborne (fixed-wing or rotary wing) friendly forces operate in this zone. By sectoring the battlefield into distinct CAS zones, UCAV integration with manned CAS systems becomes more palatable.

Now that the battlefield has been doctrinally sectored, how do you get the orbiting UCAV(s) into the CAS fight? Coordination of unmanned systems in the Medium and Deep CAS zones can be orchestrated utilizing present day deconfliction techniques and terminal control procedures. Once the UCAV is handed off to the USC, as determined by the AOC/or Air Support Operations Center (ASOC), UCAV assets can be rerouted into specific zones awaiting final attack clearance. This will almost always be via indirect control unless a FAC(A) or TAC-P forward provides direct control.[83] Close coordination between the TACS players is essential but requires no doctrinal shifts in procedures to accommodate UCAVs. The advantage the UCAV has over manned systems in these zones is defined by its endurance, sensors, and smart munitions. In a permissive environment, the UCAV could loiter at high altitudes for hours utilizing its on-board sensor suite to detect and target multiple targets while simultaneously passing information to the USC and manned shooter platforms while awaiting clearance authority to engage. Once cleared to engage, the UCAV could have bombs on target within minutes, if not seconds, and provide real-time precise BDA.

As mentioned earlier, UCAV operations within the Close zone are much more awkward due to final attack control and release clearance requirements outlined in joint doctrine. Because of the standoff capability the SDB affords the UCAV, and the lack of a wide field-of-view continuous "eyes-on-target" sensor, low altitude tactics within visual range of the terminal controller present a unique challenge. Until technology allows UCAV controllers a wide-angle view of the battlefield or smart technology allows machines to reason and decide, CAS in close proximity to friendly troops (Close Zone) should be left to manned platforms.

The Future: Air-Centric Command and Control Architecture

As the USAF moves closer toward its capabilities-based strategy of warfare combining manned and unmanned long-range systems, a robust air-centric C2 architecture becomes the pivotal element in detecting, targeting, and destroying mobile battlefield targets. Even though technology currently does not allow for an air-centric processor-based C2 architecture, such a system is regarded as the standard for future UCAV systems. Taking a step in that direction, the USAF has already defined the heart of this architecture; it's being called the Multi-sensor Command and Control Aircraft (MC2A).[84] The concept calls for combining the E-3 Airborne Warning and Control System (AWACS), E-8 Joint STARS, and the RC-135 Rivet Joint aircraft into a single platform that offers the DoD an airborne multi-sensor battlefield information and control center capable of controlling manned and unmanned platforms. While early planning figures reveal a possible future fleet of 55 Boeing 767 aircraft, significant research and conceptual engineering are required to determine the feasibility of combining three different ISR capabilities.[85]

The MC2A would become the enabler and fulcrum of the GSTF capable of developing a comprehensive picture of the battlespace, both ground and air. Through the use of advanced sensors, spaced-based data-links, and next generation smart computer software suites, the MC2A will provide the focus of what General Jumper calls "the horizontal integration of manned, unmanned, and space [platforms]."[86] Serving as the primary node for battlefield information flow, the MC2A becomes an AOC forward capable of transforming the operational directives of the JFACC (allocation of forces combined with commander's intent) into tactical-level missions.[87] Through networked ISR assets, the MC2A would be capable of gathering and analyzing sizeable amounts of information in real-time, then distribute essential targeting information to manned and unmanned systems alike. While this air-centric processor based concept would largely rely on machine-to-machine exchanges, MITL connectivity would allow for human oversight and intervention.

As this technology matures and the Air Force migrates toward the air-centric architecture, the MC2A provides a promising solution to allow airborne battle managers to control UCAVs in the Close CAS environment. Utilizing the robust sensor technology offered by a single or a multi-ship MC2A network, a USC may gain continuous eyes on target capability with enough fidelity to conduct CAS operations in the Close CAS zone.

Nevertheless, UCAV technology possesses unlimited combat applications now and in the future, including the CAS role; however, there are significant hurdles to overcome before UCAVs can effectively and safely engage mobile enemy targets within the Close CAS zone. The fratricide issue presents unique challenges in sensor and software development. Perhaps the MC2A concept will eventually allow a UCAV operator the same perspective of the battlefield as the A-10 flight lead.

CHAPTER 6

Conclusion

"We [USAF] will never again build a single-mission aircraft."
Dr. James G. Roche, Secretary of the Air Force

Unmanned aerial vehicle technology is rapidly maturing and becoming the multi-role superstar of future combat operations. The Predator's effectiveness over Afghanistan provides only a glimpse of the endless capabilities an unmanned system offers nations willing to pursue such technology. Almost 100 years ago the same was being said about the airplane. As did the manned aircraft in the early 1900s, the UCAV will revolutionize the nature of warfare in the 21st century. It may be prudent to reflect on the evolution of the airplane and airpower doctrine as the UCAV gains relevance as a shooter platform. As history reveals, service parochialisms stunted CAS doctrine development in the early years due to differing fundamental beliefs regarding the employment of airpower. Today the services are facing a similar challenge regarding UCAV operations. Within the next fifteen years UCAVs will become a substantial part of the USAF inventory. As these unmanned systems gain credibility, service parochialism may only serve as an obstruction to doctrine development. These unmanned systems will be capable of filling a number of roles across the spectrum of warfare--an ISR/shooter platform for TSTs, a reactive SEAD or strategic attack platform, and a responsive CAS platform. The possibilities are endless; however, the CAS mission presents unique challenges and may require a doctrinal shift in how the US military conducts CAS operations all together.

Doctrine and training must continue to evolve as unmanned systems gain normalcy within US military operations. As much as the CAS mission is unique, so must be the performance characteristics of potential UCAV CAS platforms. They must be survivable, accurate, and capable of providing timely and responsive support to the supported ground maneuver commander. DARPA's X-45 unmanned combat vehicle offers significant transformational technologies suited for many air missions and is adaptable to the unique environment of CAS. Air Combat Command has already developed a concept of operations for the armed and unarmed Predators outlining the CAS-like missions of FAC (A) and Killer Scouts. Indeed, the description of unmanned armed systems augmenting strike assets represents a fundamental shift in the USAF's attitude toward such systems and offers a theoretical concept of operations for UCAV systems as they relate to the CAS mission.

The X-45 possesses the elementary characteristics of capable CAS platforms--range, endurance, firepower, and a robust communications suite. Furthermore, the Y-Shaped stealthy platform is equipped with an advanced sensors package permitting precision weapons engagement from high and low altitude, deliveries through smoke and haze, and a through-the-weather strike capability. Moreover, its endurance will allow it to loiter above the battlefield for hours if not days, increasing its responsiveness twofold.

Although UCAVs offer leading edge technology, employing an unmanned system in close proximity to friendly troops is problematic on several fronts. First and probably most troublesome, is convincing the Army and other services that an unmanned system can differentiate between friendly and enemy troops and deliver pinpoint accurate weapons while limiting collateral damage. Despite the Predator's proven performance in Afghanistan, this will be a hard sell in the future. Secondly, current CAS doctrine calls for specific *final attack control* procedures that may prove cumbersome and awkward for UCAV systems. How does a terminal controller determine whether a UCAV is pointed at the correct target when weapon release happens at a range of 10-15 miles? Thirdly, the lack of a wide field of view continuous eyes-on-target sensor does not allow a UCAV controller the same visual advantage as a manned aircraft.

Until technology allows UCAVs controllers a three-dimensional panoramic view of the battlefield or smart technology allows machines to reason and decide, CAS in close proximity to friendly troops should be left to manned platforms.

Although UCAV technology today does not allow CAS operations in close proximity to troops, CAS operations beyond the FLOT is conceivable by sectoring the battlefield into close, medium, and deep zones. By leveraging the endurance capability of the UCAV, massed firepower in the medium and deep CAS zones may preclude the requirement for CAS in the close zone. Nevertheless, current UCAV technology possesses the ability to provide timely and responsive CAS operations. However, close CAS operations are better left to manned aircraft until sensor, C2, and reasoning technology is developed and proven.

As warfare becomes more complex and the USAF pursues a rapid decisive operations strategy armed with UCAVs , information and C2 become vital to effective and efficient air operations. Even though present-day UAVs are controlled by a ground-based C2 network, future C2 architectures will migrate toward air-centric machine-to-machine systems capable of creating a three-dimensional comprehensive battlespace picture without MITL interference. The USAF MC2A concept represents the initial stages of this migration toward the horizontal integration of manned, unmanned, and space platforms. Eventually, manned platforms will represent the minority, with UCAVs dominating the battlespace and fulfilling the full spectrum of Air Force missions, from Air Superiority to Close Air Support in the Close Zone.

ENDNOTES

[1] Benjamin Franklin Cooling, ed., *Case Studies in the Development of Close Air Support* (Washington D.C.: Office of Air Force History, United States Air Force, 1990), 535.
[2] Charles Barry and Elihu Zimet, "UCAVs—Technological, Policy, and Operational Changes", *Defense Horizons*, October 2001, n.p., on-line, Internet, 9 September 2002, available from: http://www.ndu.edu/inss/DefHor/DH3/DH3.htm.
[3] William B. Scott, "UAV/UCAVs Finally Join Air Combat Teams", *Aviation Week & Space Technology*, 8 July 2002, 54.
[4] Garner Johnson, "Forgotten Progress: The Development of Close Air Support Doctrine Before World War II", *Air Power History*, Summer 1999, 5.
[5] Cooling, 3.
[6] Johnson, 4.
[7] Cooling, 4.
[8] Cooling, 8.
[9] Cooling, 549.
[10] Cooling, 542.
[11] Cooling, 542.
[12] Cooling, 399.
[13] Andy Bush, "Close Air Support in the Vietnam War", n.p., on-line, Internet, 24 October 2002, available from: http://www.simhq.com/simhq3/sims/features/vietnamcas.shtml.
[14] A general-purpose bomb is sometimes referred to as a dumb bomb, in that, once it is dropped from the aircraft it can not be steered to the desired target. Dumb bombs are far less accurate than precision munitions and rely specifically on the pilot to attain specific release parameters (dive angle, speed, altitude, and sight picture depression) with his aircraft prior to releasing the weapon. General-purpose bombs rely on blast, fragmentation, and incendiary affects to destroy the intended target. The majority of weapons dropped in Vietnam were general purpose. 500 pounds refers to the weight of the weapon.
[15] Harold G. Moore and Joseph L. Galloway, *We Were Soldiers Once and Young* (New York, NY.: Random House, 1992), 149.
[16] Cooling, 543.
[17] Bush, 3.
[18] Bush, 6.
[19] Bush, 6.
[20] Bush, 9.
[21] Amy Butler. "The CONOPS With a Difference", *Air Force Magazine*, October 2001, 1.
[22] General Accounting Office, Operation Desert Storm Evaluation of the Air Campaign, Appendix II, Table 11.7, June 1997, n.p., on-line, Internet, 8 December 2002, available from http://fas.org/man/gao/nsaid97134/app_02.htm, The A-10 had an 80 percent (returned to base without crashing) return rate after being hit by enemy fire. The F-16 and F-15E had respective return rates of 50 percent and zero percent). Although the number of aircraft hit in Desert Storm was low (A-10, 20; F-16, 6; F-15E, 2) the trend speaks volumes to the survivability of the A-10.
[23] James P. Coyne, *Airpower in the Gulf* (Arlington: Air Force Association, 1992), 8-11.
[24] Rebecca Grant. "An Air War Like No Other", *Air Force Magazine*, November 2002, 33.
[25] Grant, 33.
[26] Grant, 33.
[27] Sean D. Naylor, "Long Time Coming", *Air Force Times*, September 30, 2002, 16.
[28] Grant, 34.
[29] Colonel Robert Suminsby, "Air Force Transformation" address to Air War College, Maxwell AFB AL, Jones Auditorium, 24 October 2002.
[30] Terry Somerville, "Global Strike Task Force—Kicking Down the Door", *Air Force Link*, 10 August 2001, n.p., on-line, Internet, 12 November 2002, available from http://www.af.mil/news/Aug2001/n20010810_1100.shtml.
[31] Ibid, n.p.
[32] Dr. I. B. Holley is a professor of history at Duke University. He has contributed to many Air University publications and is a frequent guest speaker at Air University schools.
[33] Cooling, 535.

[34] Ronald J. Unterreiner, Jefferey A. Brelsford, Richard J. Findlay, John F. Hunnell and Micahel F. Wagner, *Close Air Support (CAS) in 2025, Computer, Lead's in Hot* (A research paper submitted to Air Force 2025), n.p., on-line, Internet, August 1996, available from: http://www.au.af.mil/au/2025/volume3/chap07/v3c7-1.htm.
[35] Benjamin S. Lambeth, *The Transformation of American Airpower* (Ithaca and London.: Cornell University Press, 2000), 131.
[36] Ibid, 131.
[37] Joint Publication 3-09.3, *Joint Tactics, Techniques, and Procedures for Close Air Support (CAS)*, 1 December 1995, I-5.
[38] Joint Publication 3-09.3, ix.
[39] Joint Publication 3-09.3, I-2.
[40] Unterreiner, n.p.
[41] Air Force Doctrine Document (AFDD) 1, *Air Force Basic Doctrin*e, 1 September 1997, 41.
[42] By 1944, the USAAF and RAF had perfected the Push CAS method of flowing CAS assets into a prescheduled area. Known at the time as "Cabrank" for its resemblance to a line of taxicabs awaiting fares, it provided a constant flow of CAS-fighters to pre-positioned ground controllers. *This data is drawn from AFDD , page 41.*
[43] Unterreiner, n.p.
[44] Robert E. Suminsby, Jr., "Fear No Evil: Unmanned Combat Air Vehicles for Suppression of Enemy Air Defenses." Paper Submitted to the Air War College, Air University, Maxwell AFB, April 2002, 21.
[45] Barry and Zimet, n.p.
[46] "Unmanned Combat Aerial Vehicle," *UCAV Web site*, no date, n.p., on-line, Internet, 25 October 2002, available from http://www.darpa.mil/ucav/index.htm.
[47] Ibid, n.p.
[48] John A. Tirpak, "Heavyweight Contender," *Air Force Magazine*, July 2002, 34.
[49] Anne Marie Squeo, "Pentagon's Aerodynamic Shift—Ascendant Unmanned Planes May Mothball Some Manned Ones," *The Wall Street Journal*, 14 August 2020, B4.
[50] Lieutenant Colonel Roger Thrasher, UCAV System Program Office, UCAV Deputy Program Manager, Arlington VA, personal e-mail correspondence with the author, 28 October 2002.
[51] Scott, 54.
[52] Scott, 54.
[53] The RQ-1A/B Predator is a system, not merely an unmanned aerial platform. It consist of four Predator unmanned vehicles with sensors, a ground control station (GCS), a Predator Primary Satellite Link and 55 personnel capable of operating the system for 24 hours. The $40 million price tag is equivalent to 1997 dollars.
[54] United States Air Force Fact Sheet, *RQ-1 Predator Unmanned Aerial Vehicle*, no date, n.p., on-line, Internet, 5 November 2002, available from http://www.af.mil/news/factsheets/RQ_1_Predator_Unmanned_Aerial.html.
[55] USAF Fact Sheet, *RQ-1*, n.p.
[56] USAF Fact Sheet, *RQ-1*, n.p.
[57] The Global Hawk UAV is capable of autonomous operations. This includes taxi, takeoff, enroute flight, imagery collection on station, and return to base and landing without direct supervision.
[58] United States Air Force Fact Sheet, *Global Hawk*, no date, n.p., on-line, Internet, 5 November 2002, available from http:// www.af.mil/news/factsheets/global.html.
[59] John A. Tripak, "Send in the UCAVs," *Air Force Magazine*, August 2001, 59.
[60] Ibid, 61.
[61] Tirpak, "Heavyweight Contender," 38.
[62] Barry and Zimet, n.p.
[63] Tirpak, "Heavyweight Contender," 34.
[64] Barry and Zimet, n.p.
[65] Suminsby, "Fear No Evil: Unmanned Combat Air Vehicles for Suppression of Enemy Air Defenses," 49.
[66] John A. Tirpak. "UCAVs Move Toward Feasibility," *Air Force Magazine*, March 1999, 34.
[67] The "Golden BB" terminology is slang used by military members referring to an enemy round (small arms, AAA, etc) that is fired into the air with a low probability of finding its mark, but somehow hits a friendly aircraft.
[68] Barry and Zimet, n.p.
[69] Tirpak, "Heavyweight Contender," 38.
[70] Tirpak, "Heavyweight Contender," 34.
[71] Adam J. Herbert, "Smaller Bombs for Stealthy Aircraft, " *Air Force Magazine*, July 2001, 43.
[72] Ibid, 44.

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[74] Barry and Zimet, n.p.
[75] Suminsby, "Fear No Evil: Unmanned Combat Air Vehicles for Suppression of Enemy Air Defenses." Paper Submitted to the Air War College, Air University, Maxwell AFB, April 2002, source drawn from Office of Secretary of Defense, Unmanned Aerial Vehicle Roadmap, 2000-2025, April 2001, 55.
[76] Air Combat Command (ACC), *Concept of Operations for MQ-1 and MQ-2 Multi-role Endurance Remotely Operated Aircraft*, ACC/DOTR, Langley AFB VA, 2002. iv.
[77] ACC, *Concept of Operations for MQ-1 and MQ-2 Multi-role Endurance Remotely Operated Aircraft*, iv.
[78] ACC, *Concept of Operations for MQ-1 and MQ-2 Multi-role Endurance Remotely Operated Aircraft*, iv.
[79] ACC, *Concept of Operations for MQ-1 and MQ-2 Multi-role Endurance Remotely Operated Aircraft*, v.
[80] 25, Stanley W. Kandebo, "SEAD, Other Ground Attack Capabilities Planned for UCAVs," *Aviation Week & Space Technology*, October 2, 2000, 30. *The acronym USC is a notional term used by the author of this paper.*
[81] Ibid, 31.
[82] Alexander L. Koven, "Joint Surveillance Target Attack Radar System (JSTARS) Direct Support of Army/Air Force Close Air Support (CAS) Operations," *USAF Weapons Review*, Winter 2000, 29.
[83] Ibid, 30.
[84] Tirpak, John A, "Seeking a Triple-Threat Sensor," *Air Force Magazine*, November 2002, 38.
[85] Tirpak, "Seeking a Triple-Threat Sensor, 38.
[86] Tirpak, "Seeking a Triple-Threat Sensor, 40.
[87] Tirpak, "Seeking a Triple-Threat Sensor, 40.

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